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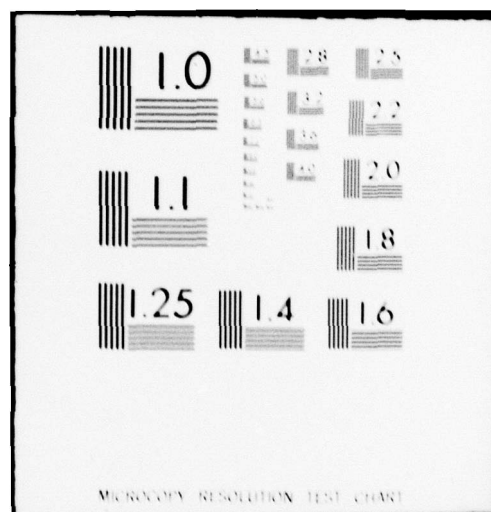
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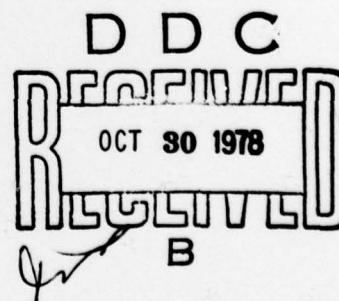
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FINAL REPORT ON CONTRACT DAAG29-77-C-0003

This is the final report on Contract DAAG29-77-C-0003 entitled "Multiple Decision Selection and Ranking Procedures," and covers the period October 1, 1976-August 15, 1978. The present contract is a follow-up to Contracts DA-31-124-ARO-D-474 and DAAG29-73-0008 which had similar missions and covered the period September 15, 1966-September 30, 1976. Because of the closeness of the objectives of these contracts, the present report lists some papers, the research for which was initiated or completed under the immediately preceding contract but which were not published in final form until after the final report for that contract was submitted. In addition it lists all Ph.D. dissertations and M.S. theses the research for which was supported in whole or in part by any of the contracts. The complete contents of the present report are described below.

The following pages list the technical reports and published papers (and those accepted for or submitted for publication) which were written with the full or partial support of the contract. The contents of most of these reports and papers have already been described in detail in the three semi-annual progress reports, covering the periods October 1, 1976-June 30, 1977, July 1, 1977-December 31, 1977, and January 1, 1978-June 30, 1978. Also included is a list of the scientific personnel supported by the contracts.

Most of the papers deal with research on the subject of "Statistical Multiple Decision Ranking Procedures," a statistical methodology pioneered by the Principal Investigator and several colleagues; some of the papers deal with related statistical techniques. An overview of the ranking and selection approach (including many important references) is contained in

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the expository paper entitled "Ranking and Selection Procedures" which the Principal Investigator delivered at the Twentieth Conference on the Design of Experiments in Army Research Development and Testing, October 1974. The importance of studying statistical problems from this point of view is now generally recognized. A new textbook entitled Selecting and Ordering Populations: A New Statistical Methodology (Wiley-Interscience, 1977) by J. Gibbons, I. Olkin, and M. Sobel describes in detail many of the procedures developed by the Principal Investigator and his co-workers. These procedures are also being incorporated in standard statistics textbooks as, for example, in Introduction to Statistics and Probability (Holt, Reinhart and Winston, 1976), pp. 341-362, by E.J. Dudewicz.

As these new techniques take their place in the textbooks alongside the traditional methods of design and analysis of experiments, there has been increasing demand on the part of practitioners to learn more about this approach and its applicability in various areas of experimentation. In December 1977 the Principal Investigator was invited to give a three-hour tutorial on "Ranking and Selection Procedures" at the Thirty-Third Annual Princeton Conference on Applied Statistics; this session was attended by more than 350 individuals most of whom expressed considerable interest in the subject; many mentioned that the procedures were very relevant to work that they were doing. In May 1977 the Principal Investigator gave a series of invited lectures on the subject to students in the Department of Biostatistics, University of North Carolina at Chapel Hill; these too were well received.

Most recently, on June 8-9, 1978, the Principal Investigator conducted a two-day tutorial seminar on "Statistical Selection and Ranking Procedures" at the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland.

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This tutorial which was sponsored by the Army Research Office-Durham with the cooperation of Drs. Malcolm S. Taylor and James Richard Moore of the BRL attracted approximately fifty attendees; about two-thirds were from Aberdeen or Edgewood Arsenal with nine additional installations being represented. The response of the attendees to the subject matter presented was extremely positive; most of the group indicated a strong desire to learn more about the topics discussed so that they could employ them in their own work.

In December 1978 the Principal Investigator will present a paper on "Optimal allocation of observations when comparing treatments with a control" at the Thirty-Fourth Annual Princeton Conference on Applied Statistics.

In summary, as experimenters are becoming more aware of the methodology of "ranking and selection," these techniques are gaining wider and wider acceptance by applied statisticians--a result which was forecast by the researchers in this area and the early advocates of these procedures. As is typical with many scientific advances, there is often a considerable lag between the creation of new ideas and their actual implementation in practice. Continuing in their lead role, researchers in the ranking and selection area must be innovative in their development of new procedures, anticipating the needs of applied statisticians. This can best be accomplished by close cooperation between the creators and users of these statistical techniques. Finally, the researchers must assume a greater responsibility in educating the experimenters in the potential benefits associated with the use of these new procedures. The Principal Investigator has been a regular participant in the Annual Design of Experiments Conferences sponsored by ARO-D, and these conferences have several times provided a forum for such educational sessions.

The Principal Investigator has submitted a research proposal to ARO-D to pursue new investigations in this important area, and to further exploit research findings already obtained. The Principal Investigator is deeply grateful to the Army Research Office-Durham for its strong support of this research activity.

Summary of Research Completed on the Contract

Technical reports, the research for which was supported in whole or in part by ARO Contract DAAG29-77-C-0003

Ramani, K.V.: "The nonparametric multisample problem," TR 319(a), January 1977.

Tamhane, A.C. and Bechhofer, R.E.: "A two-stage minimax procedure with screening for selecting the largest normal mean," TR 323, February 1977.

Turnbull, B.W., Kaspi, H., and Smith, R.L.: "Adaptive sequential procedures for selecting the best of several normal populations," TR 328, April 1977.

Barton, R.R. and Turnbull, B.W.: "A survey of covariance models for censored life data with an application to recidivism analysis," TR 333, May 1977.

Vickers, M.K.: "Optimal asymptotic properties of maximum likelihood estimators of parameters of some econometric models," TR 334, May 1977.

Hooper, J.H.: "Selection procedures for ordered families of distributions," TR 339, June 1977.

Hooper, J.J. and Santner, T.J.: "Design of experiments for selection from ordered families of distributions," TR 350, August 1977.

Santner, T.J. and Snell, M.K.: "Exact confidence intervals for  $p_1 - p_2$  in  $2 \times 2$  contingency tables," TR 371, April 1978.

Santner, T.J.: "Designing two-factor experiments for selecting interactions," TR 376, May 1978.

Tamhane, A.C. and Bechhofer, R.E.: "A two-stage minimax procedure with screening for selecting the largest normal mean (II): an improved PCS lower bound and associated tables," TR 377, June 1978.



Research supported in whole or in part by ARO contract DAAG-29-77-C-0003

Papers (published or accepted for publication)

- Barton, R.R. and Turnbull, B.W.: "A survey of covariance models for censored life data with an application to recidivism analysis." To appear in Communications in Statistics--Theory and Methods.
- Bechhofer, R.E.: "Selection in factorial experiments," Proceedings of the 1977 Winter Simulation Conference, Gaithersburg, Maryland, December 5-7, 1977, Vol. 1, pp. 65-70.
- Bechhofer, R.E., Santner, T.J. and Turnbull, B.W.: "Selecting the largest interaction in a two-factor experiment," Statistical Decision Theory and Related Topics, II, Academic Press, 1977, pp. 1-18.
- Bechhofer, R.E. and Turnbull, B.W.: "On selecting the process with the highest fraction of conforming product," Proceedings of the 31st Annual Technical Conference of the American Society for Quality Control, May 1977, pp. 568-573.
- Bechhofer, R.E. and Turnbull, B.W.: "Two  $(k+1)$ -decision selection procedures for comparing  $k$  normal means with a fixed known standard," Journal of the American Statistical Association, Vol. 73, No. 362, June 1978, pp. 358-392.
- Hooper, J.H. and Santner, T.J.: "Design of experiments for selection from ordered families of distributions." To appear in the Annals of Statistics.
- Tamhane, A.C.: "A three-stage elimination type procedure for selecting the largest normal mean (common unknown variance)," Sankhyā, B, Vol. 38, Part 4, 1976, pp. 339-349.
- Tamhane, A.C. and Bechhofer, R.E.: "A two-stage minimax procedure with screening for selecting the largest normal mean," Communications in Statistics--Theory and Methods, A6 (11), 1977, pp. 1003-1033.
- Turnbull, B.W.: "The empirical distribution function with arbitrarily grouped, censored, and truncated data," Journal of the Royal Statistical Society, B, Vol. 38, No. 3, 1976, pp. 290-295.
- Turnbull, B.W.: "Multiple decision rules for comparing several populations with a fixed known standard," Communications in Statistics--Theory and Methods, A5 (13), 1976, pp. 1225-1244.
- Turnbull, B.W., Kaspi, H. and Smith, R.L.: "Adaptive sequential procedures for selecting the best of several normal populations," Journal of Statistical Computation and Simulation, Vol. 7 (1978), pp. 133-150.
- Turnbull, B.W. and Weiss, L.: "A likelihood ratio statistic for testing goodness of fit with randomly censored data." To appear in Biometrics.

Papers submitted for publication:

Santner, T.J.: "Designing two-factor experiments for selecting interactions."

Santner, T.J. and Snell, M.K.: "Exact confidence intervals for  $p_1-p_2$  in  $2 \times 2$  contingency tables."

Tamhane, A.C. and Bechhofer, R.E.: "A two-stage minimax procedure with screening for selecting the largest normal mean (II): an improved PCS lower bound and associated tables."

Vardi, Y.: "Estimating the number of sources transmitting signals, using Starr's adaptive stopping based on capture times."

Graduate students support by Contract DAAG-29-77-C-0003

Carl Emont  
Haya Kaspi

Richard L. Smith  
Avi Vardi

Research Associates support by Contract DAAG-29-77-C-0003

Thomas J. Santner

Ph.D. dissertations and M.S. theses, the research for which was supported in whole or in part by ARO contract DAAG-29-77-C-0003 or its predecessor ARO contracts DAAG29-73-C-0008 and DA-31-124-ARO-D-474

- Awate, Prakash: (Ph.D. dissertation) "Dynamic programming with negative rewards and average reward criterion." September 1975, (TR 251).
- Bawa, Vijay S.: (Ph.D. dissertation) "Asymptotically optimal ranking and selection procedures," June 1970, (TR 102).
- Farquhar, Peter H.: (Ph.D. dissertation) "Fractional hypercube decompositions of multiattribute utility functions." August 1974, (TR 222).
- Frischtak, Ricardo M.: (Ph.D. dissertation) "Statistical multiple-decision procedures for some multivariate selection problems." August 1973, (TR 187).
- Gelber, Richard D.: (Ph.D. dissertation) "A sequential goodness-of-fit test for composite hypotheses involving unknown scale and location parameters." September 1975, (TR 266).
- Higgins, James E.: (M.S. thesis) "Bernoulli sampling plans which approximately minimize the maximum expected sample size." February 1969, (TR 65).
- Hooke, John: (Ph.D. dissertation) "Some limit theorems for priority queues." January 1970, (TR 91).
- Hooper, Jeffrey H.: (Ph.D. dissertation) "Selection procedures for ordered families of distributions." June 1977, (TR 339).
- Jakobovits, Ray H.: (Ph.D. dissertation) "Goodness of fit tests for composite hypotheses based on an increasing number of order statistics," September 1976, (TR 310).
- Kakumanu, Prasadara V.: (Ph.D. dissertation) "Continuous time Markov decision models with applications to optimization problems," September 1969, (TR 63).
- Kreimerman, Jose: (Ph.D. dissertation) "A bivariate test of goodness of fit based on a gradually increasing number of order statistics," June 1975, (TR 250).
- Marathe, Vijay: (Ph.D. dissertation) "Priority queuing systems with simultaneous server requirements." May 1972.
- Nocturne, Dominique: (Ph.D. dissertation) "Asymptotic efficiency of the maximum likelihood estimators for the parameters of certain stochastic processes." June 1970, (TR 105).



Ramani, K.V.: (Ph.D. dissertation) "The nonparametric multisample problem." January 1977, (TR 319(a)).

Ramberg, John S.: (Ph.D. dissertation) "A multiple-decision approach to the selection of the best set of predictor variables." February 1969, (TR 79).

Resnick, Mrs. Yvonne (Krammer): (M.S. thesis) "Hedging procedure for estimation of  $(k+1)$  quantiles for a population with unknown mean." September 1969.

Tamhane, Ajit C.: (Ph.D. dissertation) "On minimax multistage elimination type rules for selecting the largest normal mean." June 1975, (TR 259).

Turnbull, Bruce W.: (Ph.D. dissertation) "Bounds and optimal strategies for stochastic systems." September 1971, (TR 134).

Vickers, Mary K.: (Ph.D. dissertation) "Optimal asymptotic properties of maximum likelihood estimators of parameters of some economic models." May 1977 (TR 334).



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